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ABSTRACT

Greater understanding of reading can come about only after more basic reading research has been accomplished. Basic research should focus on what constitutes good reading, which means that the type of research that will identify characteristics of good reading must be a detailed assessment of variable effects on reading behaviors (not whether "x" improves reading, but how "x" affects reading behavior). An example of good basic reading research concerns the relation of eye movements to reading behaviors. One model of eye movement control assumes little relation between eye movements and cognitive processes, postulating that good readers make rhythmic eye movements across the page and process information from one fixation during a later fixation. Research was conducted in which visual display materials were manipulated in order to observe and carefully analyze the eye movements and changes in eye fixations of the subjects. This research contrasted with some of the assumptions made in the eye movement control model, showing the need for continued research in eye movements, and indicating how such research could be used to study skilled reading behavior. (Discussion following presentation of the paper is included.) (RL)

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What The Study of Eye Movement Reveals About Reading

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Eye Movements in Reading

At the present time there is a great variety of approaches being advocated for teaching people to read, and for helping people who read poorly to improve. One approach may emphasize the formation of accurate hypotheses, another may emphasize widening the perceptual span and speeding up the perceptual processes, another may place its emphasis on building a sight vocabulary, and still another may attempt to teach a series of specific skills which are thought to be critical for successful reading. Each approach has its advocates and its critics. It is easy for someone who is first encountering the field of reading to be baffled by this seeming chaos and to raise the obvious question, "Why doesn't someone do some research and find out what is the best way to teach people to read?" Our answer, that research of this type has been going on for decades and we are still seldom able to determine that one method is better than another, will probably cause our novice to wonder why so much research (so many millions of dollars, and hundreds of thousands of man hours) should leave us in such a state of ignorance. The excuses we give in response to that question will probably not sound convincing.

In this paper, I would first like to address the question of why so many approaches to reading can exist at the same time, and what it takes to change our present state of ignorance. My answer will be an argument for more basic research in reading, and I will then try to describe an example of such research and show the kinds of implications it can have for reading instruction.

Why we have so many approaches to reading instruction

A person who develops a curriculum for the teaching of reading is in reality working from two sets of assumptions. First, he makes a set of assumptions about the nature of the final product he seeks, which I will refer to as skilled reading. Second, he makes a set of assumptions about the sorts of exercises which will move a person from where he is to some point closer to being a skilled reader.

As I peruse various materials designed to teach reading, it appears that the authors are often making very different assumptions about what it is they are actually trying to teach. In fact, in the reading field generally, there is great disagreement about the nature of skilled reading. What is even more disconcerting, often where there is some agreement there is little evidence to justify the position being agreed upon. To a great extent, we must admit that we do not know what a successful reader is doing as he reads; we do not know the nature of his perceptual processes, nor of the cognitive processes involved in converting visual language patterns into meaning. If we were to make a list of the assertions we know to be true about the nature of skilled reading, on which we have sufficient evidence to feel highly confident, the list would be depressingly short.

One of the things we can do with facts is to show that certain theories are incorrect. If we know Fact A to be true, and Theory B is not consistent with Fact A, then we have some reason to reject Theory B as an acceptable account of the phenomenon we are interested in, or at least require that it be modified. However, when few well-established facts exist, there is little empirical basis for selecting one theory over another; that is, for keeping some theories and rejecting others. Thus, it is possible for many creative people to devise alternative views of the phenomenon, few of which can be rejected on an empirical basis. This seems to be our present condition in the field of reading. Each

person is free to adopt his view of the nature of skilled reading, and then to create a set of exercises which he believes will guide people to be able to read in that way. There is little basis, in terms of facts we know about skilled reading, to select which views are most accurate. In this situation people tend to make choices among the alternatives more on the basis of emotional factors (which approach is most compatible with the way I think about reading, which approach was favored by my favorite professor, etc.), rather than on the basis of consistency with known facts, and hence discussions and criticisms often seem to produce more heat than light.

If this analysis is correct, then one of the great needs of the reading field today is for well-established facts about the nature of skilled reading. The bulk of past research in reading has not been aimed at this goal. Only by adding to the list of things we are confident are true about the nature of skilled reading, can we begin rejecting certain particular views of reading, together with curriculum programs which are based on these views.

Of course, gaining an increasingly accurate view of the nature of skilled reading does not itself answer the question of how to help people become skilled readers. But it should lead to greater agreement on the nature of the goal of reading instruction. Our work would be greatly enhanced if we had enough knowledge to be able to agree on our goal, and then we could focus our arguments on the most effective ways of achieving it.

There are many things we need to learn about the skilled reader, including the size of his perceptual span, what aspects of the text he is using in his reading, how he integrates the piecemeal input from a series of fixations into a coherant meaning representation, what aspects of the passage he tends to retain and not to retain, the nature and amount of flexibility he exhibits in reading different materials and for different purposes, and what characteristics of the

task and the text influence which aspects of the passage he retains from his reading, to list a few obvious questions of importance. But the main point I wish to make is that the experimental investigation of skilled reading, if it can succeed in revealing facts about the nature of the reading skill, is of vital concern to our attempts to improve reading instruction. It is a most needed, and perhaps the least developed, aspect of reading research today. The entire enterprise of curriculum development in the area of reading is to some degree held back because of the lack of a clear understanding of skilled reading. If a person does not know the nature of his goal, it is not likely that he will be able to develop an optimally effective means of achieving it. In fact, I occassionally wonder what would happen if a curriculum developer had an incorrect view of the nature of skilled reading, and succeeded in producing a program which was highly effective in teaching children to read in that manner.

The process of identifying and remedying reading disorders is also blocked to a great extent by the lack of a clear knowledge of skilled reading. A reading disorder is basically a deviation from skilled reading. Diagnosis and remediation is the process of identifying precisely the nature of this deviation, and moving the person in the direction of skilled reading. However, if we do not have a clear understanding of skilled reading, it is very difficult to identify precisely the nature of the deviation. If we cannot do this, it is less likely that we will be successful to selecting an optimally appropriate approach for helping the person change in the manner desired.

The enterprise of assessment of reading development is held back by the lack of a clear understanding of the nature of skilled reading, because it makes it difficult to know just what aspects of the reading process, or of the product from reading, are the important ones to measure.

Thus, although knowledge about the nature of skilled reading does not by itself answer the practical problems associated with teaching people to read, it does have a strong influence on the way we think about how to achieve the practical goals. It determines how we conceptualize the goal, which focuses and places restrictions on the types of activities which we perceive as having some potential for usefulness in reading instruction. Thus, although not providing direct solutions to practical problems, it has the potential for fundamentally affecting curriculum development and instruction.

What type of research will lead to an understanding of reading?

There are a few factors which should be kept in mind if one has the goal of employing empirical research to add to the list of assertions about reading in which we have confidence.

Since our eventual goal is one of improving reading, it is common for studies in the reading area to be aimed directly at that goal. A common design is to treat two or more groups of subjects in somewhat different ways, one of which is often said to be "standard" instruction, and then to test with a unidimension measure of reading performance to see if the different treatments improved reading performance equally. This approach to research arises from a desire to immediately find more efficient means of improving reading. However, it is important to realize that this research design has little potential for increasing our understanding of the nature of the reading processes themselves. While it may find that certain treatments are more effective than others (and even this has seldom been conclusively shown in such research), it provides little or no information about why this is so. It reveals little about the nature of the mental operations involved, and thus the basis for why one treatment should be superior to another. A great deal of research of this kind can be carried out without making much

contribution to our knowledge about the nature of the reading processes themselves.

If we are truly interested in gaining a better understanding of the mental processes involved in reading, we must first recognize the complexity of those processes. A unidimensional measure of the "goodness" of a person's reading behavior captures little of this complexity. A more useful approach would be one which avoids the "goodness" question, and focuses on understanding what effects certain variables have. Rather than asking whether a variable, X, improves reading, we could study what effects X has on the person's reading behavior, irrespective of whether they are seen as improvements. This will require as detailed an assessment as possible of the effects of X on various aspects of the person's mental activities as he reads. This sort of detailed descriptive approach to the study of reading has a greater likelihood of adding to our knowledge of the reading processes. A second useful approach is to study a specific aspect of reading (the formation of inferences, the likelihood of retaining certain aspects of information from the passage, the likelihood of making regressive eye movements, etc.) and determine what effect certain manipulations of interest have on this aspect of reading. Again, the result is likely to be added knowledge about the reading processes themselves.

The sort of knowledge generated by these approaches to research is useful for theory-building, and may also be useful for practical applications. For instance, we may turn to such data to find which variables do seem to improve reading. However, improvement can only be specified with respect to some particular goals. The investigator is forced to specify the nature of the goal he has in mind (in what specific ways he wishes to change reading behavior), and then, having done this, he can turn to knowledge obtained from research to find

out what sorts of manipulations are most likely to produce these changes. Of course, two people may have different goals, and thus may select quite different means for producing improved reading. However, the sort of knowledge acquired from the research approaches I have described provides a knowledge base useful to each.

It appears to me that the type of research I have suggested is particularly important in the study of beginning reading. It is often difficult to determine what constitutes success in improving reading. If we manage to teach children to decode, but as a result of the instructional methods the children refuse to look at books at home, it is doubtful that we have succeeded. Or if one program gives them a large sight vocabulary so they do very well on a standardized reading test when finished, but we find that they fall behind for some unknown reason at the 3rd and 4th grades, we have not been a success. In a way, teaching reading is like raising children. It is extremely encouraging to see progress in a 3 year old, but we have to remind ourselves that we do not really know whether we are succeeding until we see the person at age 20 or 25 or 30. What may look like a success at age 3 may be putting the child on a line of development, the end product of which we would not view as a success at all.

A type of research we seem to need, then, is research which investigates the effects of variables, rather than research which simply asks whether certain manipulations improve reading. And wherever possible, the assessment should include a wide range of effects, including attitudes toward reading, what the child does with the knowledge or skill outside of formal reading instruction, and what effects are produced on their responses to later forms of instruction. Detailed observation of a relatively few children may give much more knowledge

about the effects of reading instruction variables than does a national study involving thousands where the only measure is some single index of amount of improvement.

A second factor which must be borne in mind in doing research in reading results from the complexity of reading and the difficulty of studying it.

Rapid silent reading involves vision, psycholinguistic processing, production of a memory representation, eye-movement coordination, formation of inferences, and many other complex processes, most of which are occurring extremely rapidly and so privately that the reader himself has little notion of what he is doing as he reads. There is little for the researcher to observe during the course of reading; the person moves his eyes rapidly, may show some facial gestures, and then is able to answer questions which he could not answer before reading.

A common strategy in psychological research is to turn one's attention to the study of some task which is simpler than the task we eventually wish to understand, but which seems to have elements in common with it. However, recent research has convinced us that people are very flexible in their cognitive functioning, being able to adopt different approaches and strategies to tasks which make them more efficient at those tasks, but which may not generalize to other, apparently similar, tasks.

In the study of reading, there have been many studies in which subjects identify tachistiscopically-presented word or letter strings, scan text to find targets, fill in missing words in text, etc. Assertions are then made about the nature of reading on the basis of the results of these studies. In view of the difficulty of investigating the reading processes directly, studies such

as these are certainly necessary. However, it is important to recognize that subjects in these tasks may not be behaving in the same manner, in the aspects being studied, as they do when they read. Thus, results from such studies must always be viewed with some degree of suspicion until similar results have been obtained from studies of people actually engaged in the act of reading a passage to understand its meaning.

If we wish to understand the mental activities occurring during reading, and to study the act of reading itself rather than some other task, there are two approaches which we can take. First, we can monitor the act of reading as it is in progress by some means which provides information about the nature of the processes involved. Second, we can obtain information about the product of reading by testing after the act of reading is finished, and on the basis of this information we can attempt to say something about the nature of the processes which must have taken place.

Both of these approaches are fraught with difficulties. The second approach requires one to infer processes from products. Certainly the nature of the knowledge which a person has acquired from a passage places constraints on the nature of the processes involved during reading; the processes must be capable of yielding this product. However, in most cases the information we have about the product falls far short of specifying precisely the nature of the processes which led to it.

The first approach to the study of reading is clearly the most desirable if our goal is to understand the nature of the cognitive processes involved in reading. However, there is very little that can be observed during the reading act. The most obvious type of behavior which can be recorded is eye movement behavior. I wish to turn now to the question of whether eye movement research can reveal useful information about the nature of skilled reading.

The study of eye movements in reading.

It appears that many (probably most) people in the field of reading today are convinced that the study of eye movements can reveal little about the nature of skilled reading. This conclusion is the natural result of several decades of painstaking research on eye movements in reading which has made little contribution to our understanding of the nature of reading. In addition, a number of writers in the field have developed models of eye movement control of a type which I shall refer to as Visual Buffer Models (for instance, see Bouma, 1974, and Shebilske, 1975), which assume little relation between eye movements and cognitive processes in reading. They postulate a buffer memory for visual input, a place for information obtained during fixations to be stored until it is needed for mental processing. Thus, on each fixation visual information is added to the buffer, and when the mind needs more visual information to continue its identification and interpretation of the text, it simply draws some from the buffer. According to this model, eye movements are only controlled within broad limits. The eye must move along fast enough so the buffer always has information available when the mind needs it, but it must not go so fast that too much information is put into the buffer, causing some to be lost before the mind is ready to use it. According to this model, then, it matters little where the eye happens to be directed, so long as there are regular fixations across the line of print. The good reader is assumed to make rhythmic eye movements across the page, with fixation durations of 1/5 to 1/4 of a second, and saccade lengths of about 8 or 9 letter positions. One would expect variability in fixation durations and saccade lengths on two bases: one would be physiological error, and the other would be the result of differences in reading rate for easy and difficult parts of the text, with the eye slowing down (ie., longer fixation durations and shorter saccades) in areas where the mind requires longer to process the text, and

speeding up where the text is easier to process. This model also assumes that the information obtained during a fixation is processed only during later fixations; during the fixation, it is simply placed in the buffer, ready to be withdrawn at some later time when needed. How much later (that is, how big the buffer is) is not known.

If this model is accurate, there is little reason to examine eye movement data in our attempt to understand the reading process. The regular movements of the good reader tell little about his mental processes, and perhaps only indicate where the more and less difficult parts of the text occur. Even here, they give a delayed indication, because it would be a fixation or two after visually encountering a difficult area before the information would be processed and the eye slowed down.

However, in our research at Cornell we have become convinced that this model is not an accurate description of eye movement behavior in reading, that the eye is being quite precisely controlled on the basis of nementary processes taking place in reading, and that there is much we can learn from eye movement studies about both the perceptual and psycholinguistic processes involved in reading. First, let me indicate why we believe Visual Buffer Models to be incorrect.

From the earliest literature on reading, it has been asserted that good readers show a "rhythmic pattern" of eye movements, that saccade lengths and fixation durations show little variability for good readers. When we began our studies, therefore, I was amazed to find that even good readers show a large amount of variability in their eye movement behavior. Their fixations range from 1/10 of a second to as much as a full second in duration, and the lengths of saccades vary from one or two letter positions to 14 or 15, as they read a single passage. It is true that they average around 1/5 second and 9 letter positions, but to ignore the variability present is akin to asserting that all human adults are

of essentially the same height because they average around 5 3/4 feet.

The Visual Buffer Models do admit a certain amount of variability. The eye is expected to speed up and slow down during reading. As Rayner and I (in press) have explained, such models give rise to the hypothesis that the durations of fixations and the lengths of the saccades immediately preceding or following them will be correlated. However, we found a correlation of -.006 between these measures. Thus, these two components of eye movement behavior are independent of one another in reading. They cannot be controlled by a single unitary mechanism like Visual Buffer mechanisms, but must be controlled separately. Also, there is little correlation between the durations of successive fixations (r=.11) or the lengths of successive saccades (r=.13). If these individual eye movements and fixations are being controlled, they are being controlled almost completely independently of one another. Again, these results question the type of control proposed by Visual Buffer Models.

Two types of theories of eye movement control would be compatible with the correlations just reported. Either these aspects of eye movements are essentially random, (perhaps the variability arising from physiological error as the eye attempts to achieve a regular pattern, but where little precise control is exerted), or the durations of individual fixations and the lengths of individual saccades are being specifically controlled by information available at the moment (momentary mental states). The latter possibility is particularly interesting, because if it were so, these eye movement measures may be closely linked to aspects of mental processing during reading.

As a general strategy, it would seem best to try to look for non-random patterns in the eye movement data, in an attempt to reject the first alternative. Only if we were to fail at this, should we accept the random movement position.

First, let me present data related to the control of the lengths of saccades. What determines where the eye will be sent?

In a study designed to investigate the size of the perceptual span, Rayner and I (1975) were able to determine whether subjects obtained visual information about word length patterns from text in their peripheral vision as they were reading. The subjects read from text displayed on a computer-controlled cathode-ray tube (somewhat like a television tube) as the computer monitored where they were looking. When a subject made each fixation, the computer was able to quickly change the display so that normal text appeared in his central vision, but in his peripheral vision the spaces between words were replaced by letters. When subjects did not obtain word length information from their peripheral visual area they tended to make shorter saccades. Control of eye movement behavior was somewhat related to word length patterns.

With this in mind, we calculated the probability of fixating each letter in the passage,[1] as a function of the length of the word the letter was in. We found that for letters in 2-letter words, there was a 10% chance of a direct fixation. This rose to 13% for 6-letter words, a 30% increase, and then dropped back to 11% for 10 and 11-letter words. Again, something about the word length patterns was influencing where the eye was being sent.

O'Regan (1975) reported a study in which he found that, at a particular point in his text, the length of the next saccade depended on the length of the next word. Longer words resulted in longer saccades.

Finally, Rayner found that there were substantially fewer fixations than normal in the area between sentences. There was only a 7% chance of fixating a space between sentences, as compared to about 12% for the rest of the text.

It seems safe to conclude, then, that the eye is not simply moving

rhythmically across the page, but that the distance it is sent for each saccade is being determined to some degree by characteristics of the text at that point. In particular, word length patterns are involved in where the eye is sent. However, since word length patterns are related to both perceptual factors and to syntactic structure of the text, we do not know at this time the precise nature of the control being exhibited.

What controls the durations of fixations?

The next question that arises is whether the durations of fixations are also being controlled on a momentary basis. Again, we find several pieces of evidence that specific control is present. First, it is a commonly-reported observation that abnormally long fixations frequently occur on names, dates, other numbers, and sometimes on unusual words. If it is true that names, dates and numbers are likely to occur in a comprehension test of the passage, there may be good reason for the reader to spend extra time ensuring that these pieces of information are well stored.

Earlier I mentioned that subjects do not fixate the region between sentences as often as other locations in the text. Rayner (1975a) also found that when fixations fell in this area, they averaged about 20 to 40 msec. shorter than fixations elsewhere in the text.

We have wondered whether different subjects tend to spend about the same relative amount of time fixating at different locations in the text. This is somewhat difficult to determine, since two subjects do not fixate at the same locations, so the information they have access to on their fixations is slightly different. As a first step around this problem, David Zola, a graduate student at Cornell, prepared text in which the words were spaced further apart than normal. He simply inserted 8 spaces after each word, thus placing them far enough

apart so that when subjects fixated one word the amount of visual information they received about other words was substantially reduced. We recorded the eye movements of a few subjects as they read this passage, after having read a practice passage. We then ran correlations between the fixation durations of pairs of subjects on each of the words in the passage. Prior to computing the correlation, we deleted all data for regressions, for words fixated more than once, and for first and last words on the line, since the readers showed idiosyncratic eye movement patterns at the beginnings and ends of lines. The correlations which we have obtained so far average about .35. Although the study is crude, the correlation indicates that to some degree, at least, different subjects are spending somewhat similar relative amounts of time fixating the same areas of the text. Thus, the durations of fixations appear to be controlled to some degree by the text and the cognitive activities involved in processing it.

Finally, Rayner (1975b) provides additional evidence that the durations of fixations are affected by the cognitive processes being carried out, along with evidence on the question of processing lag; that is, on the length of time between obtaining visual information and using it in reading. I indicated earlier that the Visual Buffer Models suggest that there should be such a lag.

The subjects in this study read a number of short paragraphs displayed by computer on a cathode-ray tube (CRT). The computer also monitored their eye movements as they read. As they read a particular line, a change was made in the text during a specific saccade. On one fixation, a particular word was present at a point a specific distance to the right of the fixation point; as the eye

How large is the perceptual span?

Having argued that the study of eye movements may be capable of providing answers to important questions about skilled reading, I will now provide one example of such research.

To me, one of the most fundamental questions in reading concerns the size of the perceptual span during a fixation. From how wide an area does the reader acquire useful visual information during a fixation in reading? The answer to this question will have important implications for the theory of reading. For instance, if the span were quite narrow, just a word or two on the line being fixated, the information-handling characteristics of the mind would be quite different than if the span were very large, encompassing most or all of a line, and perhaps more than one line, on a fixation. It is also important to point out that the size of the perceptual span during reading may be similar or different to that during other tasks, such as viewing pictures or attempting to recognize word or letter strings presented tachistiscopically. Determining the size of the perceptual span during actual reading requires finding some means of obtaining data from people as they read, rather than as they perform some other task. I will now describe one approach we have used to study this question, both as an example of how such questions can be answered through eye movement research, and as an attempt to summarize what we know about the perceptual span at this point.

Actually, there is probably not a single perceptual span. It is likely that the subject acquires different aspects of the visual information at different distances into the visual periphery. Perhaps at some distance into the visual periphery only word length patterns and other very distinct visual differences are detected. Somewhat closer to the center of vision, external word shape (location of ascending and descending letters) and beginning and

ending letters (those bounded by spaces, and thus not subject to interference from adjacent letters) may be detected. Finally, full featural detail concerning internal letters in the words may be available only for words within a fairly restricted area around the fovea. It is also likely that there is a region within which words can be identified sufficiently well that their meanings may be accessed whereas further into the periphery visual information is obtainable but not sufficient for identification. It is also possible that these areas vary at different places in the text, due to visual or psycholinguistic factors.

One method we used to investigate the size of these perceptual spans is reported by Rayner (1975), and was previously mentioned. The subjects were asked to read a series of short paragraphs, each displayed on the computer-controlled CRT, while their eye movements were being monitored. Each paragraph contained one word location, called the critical word location, where a display change might occur during reading. When a paragraph was first displayed, the critical word location contained either the original word, called the Base Word, or one of four other alternatives: a word having the same first and last letters and word shape as the Base Word and which fit syntactically and semantically into the paragraph, or one of three non-word letter strings, one having the same first and last letters and word shape as the Base Word, one having the same first and last letters but different word shape, and one having the same word shape but different first and last letters. Thus, each alternative stimulus differed from the Base Word in certain specified ways: whether it was a word or not, whether it maintained the same word shape or not, and whether it maintained the same first and last letters or not.

As the subject read the passage, during a specific saccadic eye movement on the line containing the critical word location, the word in that location was removed and replaced by the Base Word. Thus, if one of the other alternatives

appeared initially, then there was some fixation on which the contents of that location was different than it had been up to that point. If the subject had obtained visual information from the critical word location on the prior fixation, that information might be incompatible in some manner with the information obtained following the change. If so, we anticipated that the duration of the fixation immediately following the change would be lengthened somewhat as the reader carried out the added processing required by the discrepancy. As data, Rayner considered the duration of the fixation immediately following the display change, and then only if that fixation were centered directly on the critical word location. Thus, he considered how long the subjects looked at the Base Word in the critical word location immediately after the display change had occurred, as a function of two variables; first, what sort of stimulus alternative resided in that location prior to the change, and second, how far to the left of that location the previous fixation had been. We assumed that if the previous fixation had been quite far to the left of the critical word location, little visual information would have been acquired from it, and the change would not be detected. The results showed that when the prior fixation was more than 12 letter positions (3° of visual angle) to the left of the critical word location, little or no specific information about the word was acquired from it (another study showed word length to be an exception). That is, when the prior fixation was that far to the left of the word, the durations of fixations on that word following a display change were no different than the durations when no change had occurred. When the prior fixation was less than 12 letter positions to the left of the word, a display change in that word location caused a substantial increase in the duration of the next fixation. Thus, it appeared that information about both word shape and about initial and final letters was being obtained from words which began less than 12 letters to the right of the fixation

point. Finally, if the prior fixation was more than 6 letter positions from the critical word location, it made no difference whether that word location initially contained a word or a non-word letter string. Apparently, the subjects were obtaining visual information from words beginning 7 to 12 letter positions to the right of their fixation point, but were not making semantic interpretations of words in this region. When the eye was less than six letter positions from the critical word location, the occurrence of a non-word in that location both inflated the duration of the fixation prior to the display change, and substantially increased the duration of the fixation following the change. In summary, the results indicated that the subjects acquired certain visual information from words beginning up to 11 or 12 letter positions to the right of their fixation point, but seemed to make semantic interpretations of words lying no more than 6 letter positions to the right. Other studies we have conducted have indicated that good readers obtain word length information from words lying more than 12 letter positions to the right of the fixation point (McConkie & Rayner, 1975), and that they acquire little if any useful visual information more than 4 letter positions to the left of the fixation point, if that far (McConkie & Rayner, 1974). The word length information, as previously mentioned, seems to be used in guiding the eye. The visual information about letters beyond the region of semantic identification may also be facilitating reading. Rayner and I are presently conducting a study in which the subject fixates a point on the screen, a letter string is then displayed some distance to the left or right of his fixation point, and he looks over at the word and speaks it aloud. We measure the time until his vocalization begins. In most conditions, the stimulus initially displayed on the screen is replaced by another word as his eye moves over to look at it. The main independent variable is the relation between the initially displayed string and the word with which it is replaced and which the subject

must identify. Generally the more similar the initial stimulus is to the final word, the faster the subject is able to say the word when he fixates it. Thus, he must obtain some useful visual information from the original letter string on one fixation which then facilitates his identification of the word on the next fixation. This study does not involve normal reading, so its results can only be suggestive about the reading process itself. However, it gives some support to the possibility that information about visual characteristics of words lying more than 6 letter positions to the right of the fixation point on one fixation is useful in facilitating the identification of those words on the next fixation.

Thus, by tying specific display changes to the subjects' own eye movement behavior, and then carefully analyzing their eye movement records in reading, we have obtained evidence that the region from which the subjects acquire useful visual information during a fixation is much narrower than we had previously supposed. The region from which these relatively skilled readers were identifying words during a fixation was less than the size of most phrases in text, even if their fixations happened to be centered optimally within the phrase for its perception. This region was also smaller than the region from which subjects are able to identify words when they are presented tachistiscopically (Bouma, 1973). Thus, the assembling of information concerning phrases and larger linguistic structures must occur across fixations, rather than directly perceiving such structures on each fixation.

Clearly, much additional work needs to be done on this question, in order to investigate individual differences, differences at different points in the text, and differences between skilled and less skilled readers, but the techniques seem quite capable of providing answers to these questions. And for now, we at least have a "ball-park" answer to the question of the size of the perceptual

span of skilled readers which begins to have educational implications.

Educational Implications

Being able to identify the size of the perceptual span in reading is but one small part of the total process of understanding the nature of skilled reading. However, if further studies support the work which we have done so far, the facts which will be established will place specific constraints on the types of models of skilled reading which can be viewed as acceptable. Any theory which supposes the reader to obtain visual information from, and semantically interpret, a large area of text (a phrase, sentence, or line at a time) during a single fixation is probably out of harmony with reality. Any view of reading instruction that assumes that the distinguishing characteristic of poor readers is their small perceptual span, and that this small span causes them to be unable to assemble the meaning from the text, is also likely to be rejected. We have not studied the size of the perceptual span of poor readers, but we have artificially reduced the span of good readers, to see what effect this would have on their reading. We were able to do this through computer techniques for controlling the text display on the CRT as they read. With each fixation, the computer modified the display so that at the point of the subject's fixation only 9 letters of the text were seen, and the letters to left and right of this small area were replaced by x's. Thus, only 9 letters of useful visual information were available on each fixation. This essentially turned the subjects into "word-by-word" readers. The question was, did this cause their comprehension to drop substantially, as has been suggested occurs with word-by-word reading? The results indicated that the subjects' reading rate was substantially slowed, with shorter saccades, longer fixations, and more regressive eye movements. However, there was only a slight, non-significant drop in their scores

on the retention test. It is clear that there was no great drop in comprehension, as might have been expected. We have not yet carried out the studies necessary to establish whether poor readers do have narrower perceptual spans than good readers do, but the results just presented provide no support for the notion that a narrow perceptual span is the cause of poor comprehension by poor readers. This being the case, it becomes doubtful that performing exercises which try to broaden the size of the perceptual span are likely to directly improve comprehension in reading. It should also be noted that we do not have evidence at the present time that exercises commonly believed to broaden the perceptual span actually increase the size of the perceptual span in reading. With the technology described earlier, we are now in a position to test this claim. We should also note that even if these exercises do not broaden the perceptual span they may still have a facilitating effect on reading for some other reason. That possibility also needs further exploration.

The future potential for eye movement research in reading

As I have tried to show, recent research seems to have established that skilled readers do not simply move their eyes in a rhythmical pattern, but that where the eye is sent and how long it remains in that location is controlled on a momentary basis, and reflects certain aspects of the processing occurring at the time. It is this characteristic that opens the door to using eye movement research to study aspects of reading other than the eye movements themselves. The studies described which investigated the size of the perceptual span, using eye movements both to control the display and to provide a detailed record of the reading behavior, are an example of how this can be done. I believe that we now have the potential for seeking answers to a number of other questions about the nature of skilled reading through eye movement research, as well. The fact that eye movements are rather sensitive indicators of disruption in reading makes it possible

to detect whether and when certain irregularities in the text are detected during reading. It appears likely that fixation durations reflect the amount of processing, at some level, which must occur involving the visual information being perceived on that fixation. Detailed theories of visual, psycholinguistic, and memory processing will undoubtedly predict differences in the amount of cognitive work required at different points in the text, and fixation duration patterns are likely to become a primary data source for testing such theories. Finally, the capability of making display changes contingent on eye position, so the display is modified from one fixation to another, provides a powerful method of exploring aspects of the perceptual processing in reading.

The study of eye movements in reading is obviously only one approach to the study of reading. At Cornell, we are also engaged in an attempt to identify what information is retained from a text, and how the characteristics of the text and the task demands influence this. These questions and many others, will require quite different research approaches. However, the important thing about a number of approaches to reading research which are presently being developed is that they have the potential for yielding specific knowledge about the perceptual and cognitive processes involved in reading. Careful studies using these approaches will add to our list of assertions that we can say we know about reading, about which we have substantial supportive evidence. This body of facts should allow us to gradually weed out views of skilled reading which are not in harmony with reality, and will exert pressure to produce new theories which are in harmony with the available facts. As our understanding of skilled reading develops, the activity of curriculum building and reading instruction will have a firmer foundation on which to build. I believe that progress in the study of skilled reading will be reflected in all aspects of the field of reading.

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Footnote

1. When speaking of eye position, I will refer to the eye as "fixating" at a certain location. This simply indicates that the position of the eye is approximately that which would occur if we asked the subject to look directly at that location. It is not meant to suggest that the reader is specifically giving attention to that particular letter or word.

OPEN DISCUSSION OF McCONKIE PRESENTATION

TRABASSO: I was very interested in that last report, because you found that manipulating the size or amount of information that the person is allowed to see is unrelated to comprehension, and that enormous disruption of the eye movement activity is also unrelated to comprehension. So it raises some question about the role of eye movement activity per se, in comprehension. The variable you are controlling is the number of letters taken into account, but the immediate effect of that manipulation is to disrupt the normal eye movements during reading. Yet you get no effect on comprehension. So, in some sense, you establish a lack of correlation between the kinds of eye movements and degree of comprehension.

McCONKIE: You have to recognize that what I am interested in is what I can learn from those eye movements, what I can learn about the skilled reader or about the reader that I am studying.

Now, I am not going to try to argue for the old position, that a person who reads well has got to show this particular pattern of eye movements. I am not sure that is going to be so, but I am sure that I can, by making manipulations, begin to answer questions about what's going on cognitively as the person reads, if I set up my experimental situation right. When you restrict the text available, a person reads in a very different way in order to get the same kind of comprehension when he isn't so constricted. You put him in this strange task, where he can only see very little on each fixation, and he has to adopt some very different strategies apparently. But he is able to overcome that particular problem, and compensate for it, and adjust his strategies, and succeed in understanding what the text says. I don't think that rules out a relationship between eye movement telling us something about the nature of the comprehension

process.

TRABASSO: I don't deny the extremely useful finding and methodology you have here, with respect to the duration of the fixation as indexing semantic changes. But what I am intrigued by is your experimental data, which show that very different eye movement strategies yield the same product. It is not clear to me then what kind of process or process models you are going to come up with from studying eye movements, when in fact different kinds of eye movement patterns lead to the same outcome. That's the problem.

McCONKIE: Well, my interest is in finding out what people are doing. Are you saying that different people may be doing things that are quite different? And can I, using this technology, figure out what these different people are doing? I suppose you would also say that the same person, at different times, may use different approaches to reading.

GREGG: George, I now see why you asked me the question you did the other morning, what is true and what is not true in the materials that I proposed, and I guess I would submit that the kinds of facts that you are looking for are like the balls and strikes in baseball, where the umpire says, "They ain't nothing until I call them." He has a theory about where the shoulders are, and where the knees are, and where the strike zone is, and I see you proceeding without any kind of framework for knowing a fact, when you come across one. The problem is that much of our scientific observation gets reinterpreted in the light of new ways of putting so-called facts together.

McCONKIE: I was sure that I would get that comment.

GREGG: Right. Now that I have made my comment, have you tried to define skilled reading ability? If you recall, we had a whole bunch of skilled reading tasks, that people carried out. Would you care to make more explicit what you consider skilled reading?

McCONKIE: The main thing I tried to do was identify people who seemed to read quite well, relative to the people around them. So for some of the studies, we went to a high school, to the people who were in charge of the reading instruction there, and we said, "Out of your high school who are your 25 best readers?" And we used them.

In another case, we put an advertisement in the newspaper, and they came in, and we gave them several tests and tried to pick out the ones who seemed to be doing the best. No, I can't identify the ideal type of skilled reader, for a number of reasons. We put one person in front of the eye movement equipment, he reads very quickly, and makes regular eye movement patterns, and he doesn't remember anything. And the next person may come in, and do a lot of regressing. We look at his eye movement data, and say, "Good heavens, here is a person who can't read," and he gets nine out of ten questions correct. (The other person got two out of the nine.) I bring somebody in, he goes whipping through at 700 words a minute. I ask him 10 questions, and he can only get two of them right. Then we say, "Okay, read the next passage," and his reading rate drops from 700 words a minute down to 250.

ROSNER: I am not clear about your method.

McCONKIE: I went over it very rapidly.

ROSNER: Just simply, the change that occurs in the letter and the word that was off to the right is an abrupt change, it is a very quick change? And it's all letters the same time?

McCONKIE: Yes.

ROSNER: Do you think perhaps what you are measuring is sensitivity to changes in peripheral field?

McCONKIE: No.

ROSNER: Why not? What is the distance of the subject from the screen?

McCONKIE: The nature of the text is such that we have four letters per degree of visual angle.

ROSNER: So you are only two degrees off fovea, when you get to 12 letters?

McCONKIE: That's right.

ROSNER: What makes you say you are not measuring, then, observation of changes in peripheral field instead of foveal changes?

McCONKIE: First of all, different kinds of changes result in different effects on the reader's eye behavior, in a rather understandable pattern. We are clearly not simply dealing with effects due to the simple presence of absence of stimulus change in the periphery.

ROSNER: Next a question of methodology. The words that elicit the longer fixation are words that are semantically inaccurate, right?

McCONKIE: No. They are semantically and syntactically appropriate. In one case the robbers are guarding the police with their guns, in the other case they are guarding th palace with their guns.

ROSNER: But you are getting changes, you explain, because of the anticipation in the movement? In other words, something is occurring in peripheral field.

McCONKIE: I am not quite sure what you are asking at this point, I guess.

ROSNER: If I am looking here, and you flicker something there, when I move to there I am asked to spend a little bit longer looking at what was flicking.

McCONKIE: Well, the interesting thing is, depending on what's changed, you spend different lengths of time.

ROSNER: Well, that was my point, what elicits the longer change, the longer stay there?

McCONKIE: Well, it depends on where you fixated previously.

ROSNER: Well, then I will have to see your paper.

McCONKIE: Right. The thing to do is look at Keith Raynor's article in Cognitive Psychology.

DANKS: It seems to me that the bottom line is that good readers are extraordinarily adaptable and flexible in terms of getting information off the page. So I still come back to whether studying good readers is going to help us understand what the poor reader is doing.

McCONKIE: I decided specifically not to start studying poor readers, because I feel that I can only understand poor readers in relationship to how they differ from good readers, and so my first task has got to be to find what the good readers are doing.

DANKS: It seems that you are finding out what the good reader can do when he is faced with a very poor reading situation.

McCONKIE: This task was just a sort of a sideline thing, to see if that narrow perceptual field causes your comprehension to go to pieces.

The thing I want to do is to get the person in a situation where he is reading a passage, he knows the kinds of questions he is going to answer, he knows his primary task, he is to read that passage to understand it, and then to learn what he is doing. In fact, we pay him according to the number of questions he can answer correctly, to get him to really try to understand it and remember it. That's what I am interested in doing, and I won't point to this as an example of that kind of research. I threw that in primarily because I thought it would be of interest to this particular group.

GUTHRIE: I am interested in the relationship that you mentioned at the outset of your paper, between this research and instruction. Let me see if I understand what you said. You said, as I heard it, that we need to know about skilled

reading in order to get a clear establishment of goals for curricula, and we need to get clear goals stated for curricula before we can develop methods that might be likely to achieve those goals; therefore, the study of skilled reading is essentially prerequisite to valuable work in instructional design.

It seems to me that might be debated. First of all, I have a very rough analogy, you might look at the comprehension that we have of adult language versus the comprehension that we have to developmental psycholinguistics. Certainly something has been learned about how children acquire knowledge, in the last 10 years, in the absence of total knowledge about how adults process language.

McCONKIE: Oh, I wouldn't say that at all. I think that that was stimulated by a theory of competence of the adult language user. That was what stimulated the developmental research, and that's what made it useful.

GUTHRIE: The progress in adult language has certainly occurred in parallel with progress in developmental psycholinguistics, and I should think the same would occur in reading. Knowledge about how skilled readers function can develop in parallel with knowledge about how children learn, and how instruction can foster that acquisition. I don't think we have the kind of prerequisite situation that you originally described, and those kinds of prerequisites are discomforting. I don't think they are really mandatory.

McCONKIE: I certainly don't want to be that prescriptive; I certainly recognize that we need good, descriptive research at all levels of reading, so that we can understand what people are doing at the different levels of reading. But as I tried to understand what people are doing at other levels, I keep getting hung up

because I don't know what it's leading to. Clearly, not all research should focus on one aspect of reading, before any research starts on another aspect. But what I have seen, as I look across the literature, is a tremendous focus of research on the beginning reader, and very little good research being focused on the skilled reader. I would argue for the importance of my position, without saying that that should be prescriptive for everybody.

GUTHRIE: That kind of reformulation, as I heard you give it, makes good sense to me. I think in parallel it's got every legitimate reason to be conducted. It's vital in parallel with other things.

McCONKIE: I respond to criticisms which I have received from my colleagues. What concerns are people in education going to have about the kinds of things I am doing. First, why study skilled readers? Second, for heaven's sake, why look at their eye movement patterns? And what I tried to do here was justify those directions in research, by saying that they are not only useful, but they are particularly important.

ROSNER: Would you speculate as to how the unskilled reader would have done with that same text?

McCONKIE: I can't speculate at all. You know, I have never put them in that situation, and I don't know.

ROSNER: Would you predict it?

McCONKIE: Well, they differ in everything else, don't they?

JUST: You said that eye fixation research would help us characterize the nature of skilled reading. One of the questions that comes from your research is, how do we process the information we don't look at directly? Could you provide a short list of other questions we could each hope to answer, each within six to eight months? What kind of characterizations of skilled reading can we get from eye fixation research?

McCONKIE: We are all set to start working on the question of what aspects of the word or the text are actually being acquired during a fixation; what letters in the word, how much of the word must one pick up during a fixation, what aspects of the word are sensed in the process of reading. All of the studies have been done with tachistoscopic presentations which I don't think tell us much about what goes on in reading, and how it is the language constraints influence what aspects of the text we pick up during a fixation.

Any time you get into a theory of the language processing involved in reading, you find yourself deciding that a lot of cognitive processing must take place at some places in the text, and not much at others. And I think we can get at that using fixation durations.

We are also playing with the technique by which I think we can get at the sequence of levels of processing that are involved.

If we think of processing being visual, making contact with lexicon, and perhaps integration within word groups, or phrase-type groups, and finally the identification of the case role of that particular set of information, I think we can determine the point at which those different types of integration occur, and the lag time between one and the other, and show that there is a sequence in those steps. We just have a little pilot data on that. It convinces me that we

are on the right track; that is, using eye movement data to get at the sequence of processes involved in integrating the meaning of the text.

SUPPES: I am not clear about what you want to say about skilled readers. For example, we can talk about skilled talkers, and we know we can identify lots of differences in the way people talk, and so that if you record somebody's talk or writing, you can identify that person by the characteristics of his talking. To what extent, in the study of skilled readers, do you expect striking individual differences in skilled readers, so that, for example, if you talk about eye movements, what kinds of differences do you expect about people who perform at comparable levels? What are the salient generalizations you would tell us about their differences?

McCONKIE: I've just gotten started on this work, but let's take the question of perceptual span. I believe we now have a technique for identifying, on the individual person level, what the size of the region is from which they are picking up visual information of different types. Now, if I can do that for individuals, I can come back and tell you in a couple of years whether there is a lot of variation or not. And that's going to be important to know because the way that we go about doing other things will be heavily influenced by that.

The question of variability is simply an empirical question. Can our research techniques pick up information about individuals? We have techniques that are quite capable of manipulating people's reading strategies, so that we can not only study individuals, but also within individuals as they adopt different strategies. It is a matter of finding techniques, and going in and answering the question about variability. I can't answer the questions before getting into them research-wise. But the techniques are now becoming available

to study them in ways that we have never been able to before.

CARROLL: I don't think you have to be very defensive about your notion of studying skilled readers. However, I would underline the necessity of defining what a skilled reader is, because I am sure that we already have a lot of techniques for differentiating different kinds of skilled readers in terms of vocabulary and syntactical competence. I would think that your research should continue along the line of studying a whole host of variables in your presentation situation, in the text and its readability, its vocabulary, et cetera.

It looked to me as if a lot of your variability simply comes out of some subjects's perception of the task requirements.

One of my colleagues at North Carolina is starting to study skilled Braille readers, because the Braille reader does have a very small perceptual span, and what we are trying to find out is whether the slowness of the Braille reader, which rarely exceeds about 90 words per minute, is simply because of that small perceptual span.

And it's going to be looked at by studying sighted Braille readers, and to see whether their perceptual span, which is inevitably larger, will enable them to read much faster than the blind Braille readers. There is a connection here between your research and this matter of Braille reading.

McCONKIE: Yes, we have a student at Cornell who has become interested in working with Braille readers, too.

Recess